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Technical Report No. 4

AN INTEGRATED-SELECTIVE KEY FOR THE PHOTO IDENTIFICATION OF IRRIGATION STRUCTURES OF A GRAVITY-FLOW IRRIGATION SYSTEM

By

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Introduction

There are more than 200 million acres of irrigated land in the world. About one-third of this lies in Pakistan and India. Additional areas occur throughout the world. (See Figure 1).

Water to irrigate these dry lands comes from three principal sources: natural streams, underground reservoirs, and surface reservoirs. Most modern large-scale projects now depend on surface reservoirs to hold flood waters in check until needed on the land for irrigation. Many such reservoirs have been built in our west; others have been built or are now under construction in the African Sudan, India and Pakistan, and in the semiarid regions of Russia. Water from the surface reservoirs is carried in an elaborate system of canals by the force of gravity to the lands to be irrigated.

This key is intended to provide the photo interpreter, untrained in agricultural geography or land use economics, with the means of identifying irrigation structures in an area characterized by a gravity-flow irrigation system. The key has been so arranged that features within such a system can be identified by reference to the appropriate portion of the key. Because of this arrangement, the key may be classified as an integrated-selective key.

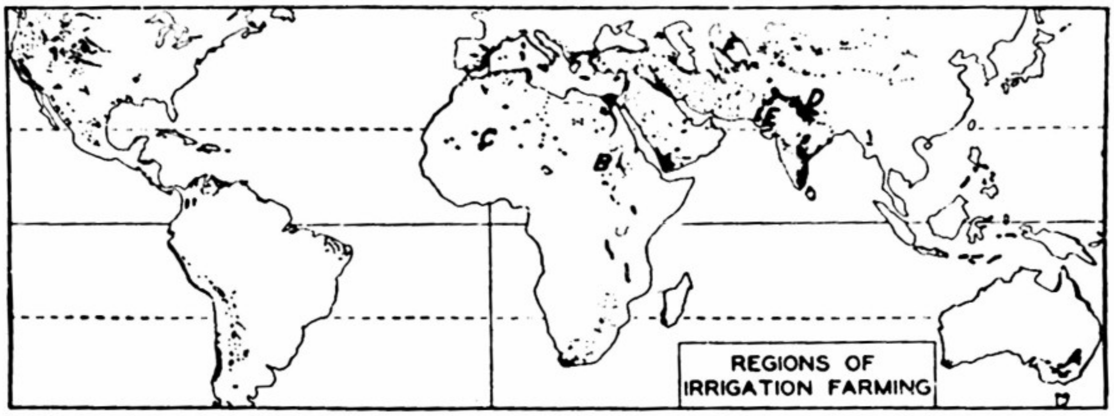


Figure 1. Areas of Irrigation Farming. Outstanding examples of large gravity-flow irrigation systems including dams, reservoirs, and canals outside the United States may be found in (A) the Murray River Valley of Australia; (B) the Upper Nile Valley of the Anglo-Egyptian Sudan; (C) along the Niger River of French West Africa; (D) the Punjab area of Northwestern India and Pakistan; (E) along the Indus River of western Pakistan; and (F) along the Sir Darya and Amu-Darya Rivers of Russian Turkistan.

Studies were carried on in the Greenfields Irrigation District, Fairfield, Montana during 1951. (See Figure 2). Photo interpretation of vertical stereopairs was integrated with detailed field observations of gravity-flow irrigation structures and associated farm practices. Ground photographs in stereopairs were taken of characteristic irrigation structures. The field studies were followed by office studies in which photo appearance of irrigation features was checked. The key summarizes descriptions which help to identify irrigation structures from aerial photographs in stereopairs.

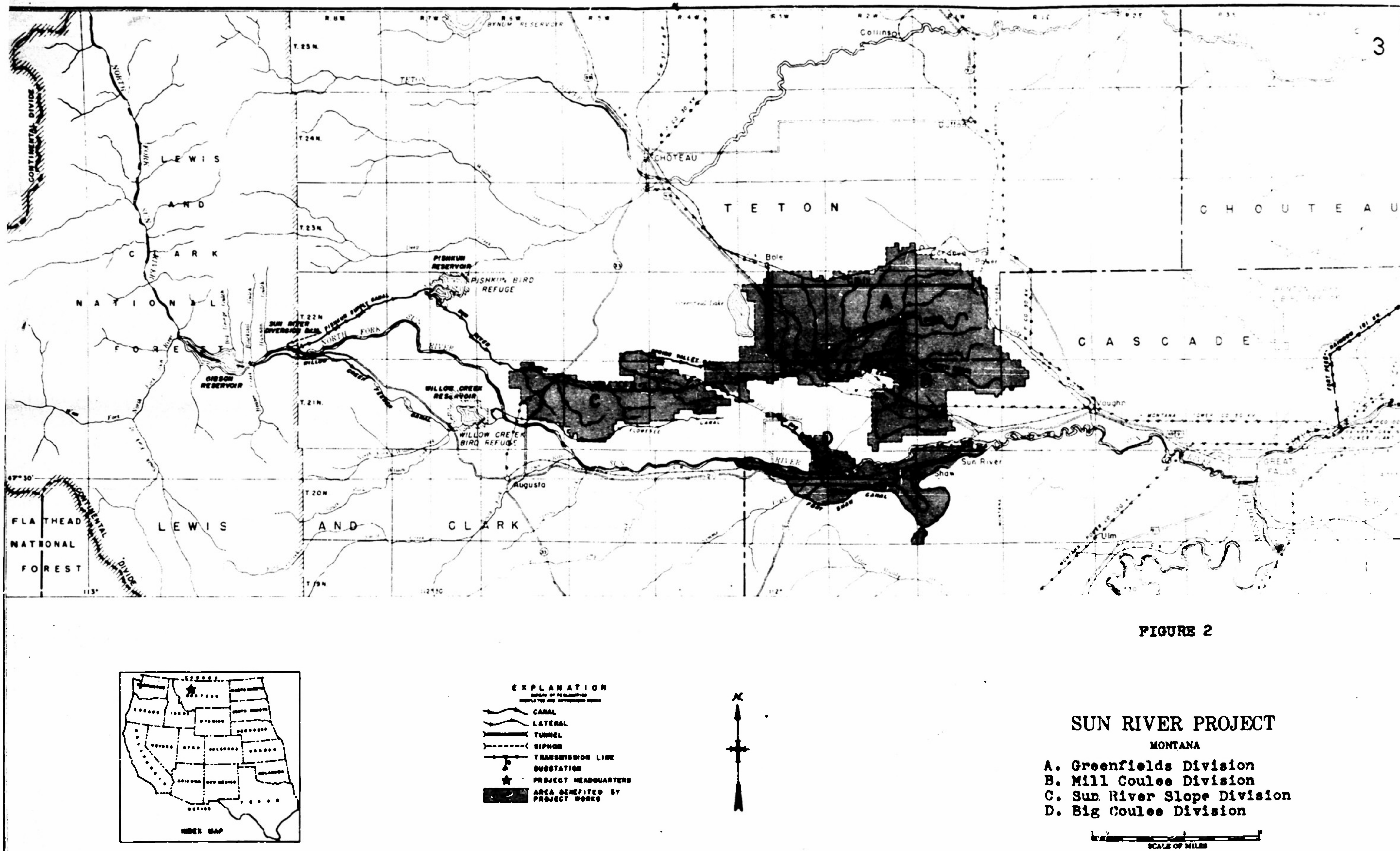


FIGURE 2

SUN RIVER PROJECT

MONTANA

A. Greenfields Division
B. Mill Coulee Division
C. Sun River Slope Division
D. Big Coulee Division

The Greenfields Irrigation District

The Greenfields Irrigation District of the Sun River Project, Fairfield, Montana, was selected as an area for field study for four specific reasons. (1) The Project receives water from the Lewis Range of the Rocky Mountains which lies about 45 miles to the west. The general eastward slope of the land makes irrigation possible by gravity-flow; hence the Sun River Project has within it those structures which are common to gravity-flow irrigation systems throughout the world. (2) The Sun River Project is one of the oldest of the federal reclamation projects in the United States. Construction on the Greenfields Branch was begun in 1913 and was largely completed by 1925. No new irrigation development is contemplated. Thus, the District has probably attained its maximum physical extent, although much remains to be developed within the area to insure maximum efficiency of operation and return for the money invested. (3) The project is a single-purpose project. As a study it provides none of the complications of multi-purpose developments, and is more representative of the kind of gravity-flow irrigation projects which have been developed elsewhere in the world. (4) The Project is small enough to be understood in its entirety; yet large enough to be representative of its kind.

The Greenfields Irrigation District is located about thirty-five miles west of Great Falls, Montana, between the Sun River and Muddy Creek. Altogether the District occupies about 90,000 acres of irrigable land on three distinct bench levels. Each of these levels is bounded by abrupt scarps.

The source of water for the District is the Gibson Reservoir which contains the impounded waters of the Sun River. The Gibson Dam was put into operation in 1929. Water is delivered the entire distance from the Gibson Dam by gravity flow. The distribution system for water on the project consists of 169.8 miles of canals and conduits, 441.9 miles of laterals, and 190 miles of drains.

The Greenfields Irrigation District of the Sun River Project lies wholly north of the Sun River on a series of benches, the lowest of which stands at approximately 3500 feet and the highest at 4300 feet above sea level. Although the entire District is served by the same main supply canal, within it are four distinct and separate divisions (Figure 2). Two of these divisions, comprising 70,000 acres of irrigable land, are the largest and most important parts of the Greenfields Irrigation District. They are bounded on the west by Big Coulee and Greenfields Lake and on the north by Muddy Creek. These two units are known as the Greenfields Division and the Mill Coulee Division. The third unit, The Sun River Slope Division, lies in a narrow belt west of Big Coulee on a terrace level of Sun River and at about 3900 feet above sea level. This Division is 12 miles long and averages 5 miles in width. It comprises about 12,000 acres. The fourth division is of relatively minor importance (3200 acres), and lies along the lower course of the Big Coulee where it empties into Sun River. It is referred to as the Big Coulee Division.

The administrative and trading center of the entire Greenfields Irrigation District is Fairfield, Montana. This small business town lies midway along the east-west extent of the District in the southwest corner of the Greenfields Division.

The Greenfields Division of the Greenfields Irrigation District, with which this report is concerned, consists of three distinct levels, descending from south to north toward Muddy Creek. Small, but well-defined scarps mark the edges of these levels. The Division is fairly regular in its surface, except towards the east where Grasshopper Spring and Long Coulee, tributaries of Muddy Creek, have cut deeply into the benchlands. The generally level character and parallel nature of the three levels, or benches, have facilitated distribution of water for purposes of irrigation.

The Greenfields Division drains into Muddy Creek to the north and east, and into Greenfields Lake to the west. Muddy Creek is a major tributary of Sun River, draining the uplands between Sun and Teton Rivers. Although it is a major stream, it is dry for part of the year as are the coulees. Nonetheless, some water is contributed by wastaways from the Greenfields Division. Greenfields Lake to the west is thought to be a former glacial lake in front of a terminal moraine. It is now imperfectly drained and thus occupied by alkaline water. The lake varies annually in size according to the amount of precipitation.

Settlement of the Greenfields Irrigation District

The development of irrigation farming brought drastic changes in the settlement pattern and economic life of the Sun River Valley. Prior to the application of water, the Greenfields Irrigation District was given over to dry-farming and grazing. At that time, the District is believed to have supported about 50 families on a total of 73,000 acres.

The first move to irrigate the Greenfields District was made in 1884 on the instigation of private capitalists. In 1889, the area was surveyed by the U.S.G.S. and potential reservoir sites were located. In 1902, several settlers filed homestead and desert claims in the District and organized themselves into the Kilraven Cooperation Canal Company to carry out plans which had been abandoned by the Columbian Canal and Colonization Company in 1893. They, too, abandoned efforts and actually completed only about one-tenth of the construction work. It became apparent that irrigation of the bench lands adjacent to the Sun River Project could not be developed from local financial resources. After the passage of the Reclamation Act in 1902, serious attention was given to the development of an irrigation system under the auspices of the federal government. The construction of the Sun River Project was finally authorized by the Secretary of the Interior in 1906.

To expedite irrigation development and to regulate farm units as to size and shape, it was necessary to bring irrigable land under administrative control. On projects constructed by or receiving water from the Federal Bureau of Reclamation, the total acreage eligible for delivery of water is 160 acres in any one ownership, or 320 acres for man and wife, until such time as all construction charges have been repaid. The law does not limit the acreage which a person may own; only the acreage to which water can be delivered. This practice comes under the "excess-land law" and applies only to those projects which use water supplied by the Federal government under reclamation law.

The procedures followed by the United States Government through the Bureau of Reclamation in converting public and other lands to irrigation farms includes the laying out of farms, preparing the land for cultivation, putting in laterals, sublaterals and head ditches, and selecting and placing settlers on the land.

The laying out of farms on public-land projects is as precise a procedure as the nature of the operation will permit. First, the irrigable acreage is subdivided so as to produce farm units that are economically feasible. In general, in the Sun River Valley new farm units were laid out in 80-acre tracts, 1/2 mile north and south and 1/4 mile east and west. This was considered to be the most economical arrangement in terms of the mechanics of water delivery and topographic restrictions. Insofar as possible each farm unit contains some dry land in addition to irrigable land. Farms were made as nearly equal in value as practicable, and each farmstead was located with access to a road. Finally provisions had to be made for the removal of waste and storm water from the farms and at the same time provide for the drainage of the roads.

In general, the orientation of each farm unit was in terms of the slope of the land and the layout of main laterals. It was found that the farm unit layout, however, greatly influenced the spacing of sublaterals. The plan adopted made it possible to construct sublaterals at intervals of one-half mile to reach each farm unit. These sublaterals were dug along farm unit boundaries, if at all possible, and were extended from one to two miles. Each was constructed to carry water at the rate of from ten to twenty cubic feet per second at their turn-off from main laterals.

The resulting pattern of settlement is striking indeed to even the casual traveler. The large holdings of dry-farmed land give way sharply to small irrigated farms. The change is sudden and well-marked on the landscape. Aerial photographs record it just as effectively and strikingly. (See Photo 1).

Photo 1. Aerial photo of irrigated and non-irrigated land. This shows sharp contrast of the irrigated fields of the Greenfields Irrigation District with the non-irrigated wheat fields to the north of Muddy Creek. Note the strip-farming practices in the wheat growing area. Fields of irrigated crops are generally rectangular in shape. Field ditches are plainly evident. Roads follow section lines of township-range survey system. Scale: 1:27,000 (USGS, Photo GS-Cl, 7-4-46, #1 12).

Irrigation Structures Associated with a Gravity-Flow Project

A gravity-flow project is generally characterized by three major types of structures: storage facilities, a carriage system, and distribution features.

Water may be supplied for gravity-flow irrigation systems from wells, natural stream flow, or stored flood water in reservoirs built for that specific purpose. The natural flow of rivers is generally insufficient to meet all irrigation requirements in a dry or semiarid region throughout the growing season. It may be ample until the end of the flood season; but then the natural river flow drops sharply below irrigation requirements. As knowledge concerning the cycle of water in rivers grew, it became apparent that if flood waters could be captured and stored, not only would existing areas be assured of sufficient water to mature late-season crops, but much new land could be added to the irrigated areas. Most gravity-flow irrigation systems today, therefore, have large reservoirs or a series of reservoirs which serve to impound flood waters. Water is released as it is needed to meet the irrigation requirements during the dry season.

The carriage system consists of diversion dams, supply canals, tunnels, siphons, and the like. These carry water from storage facilities to the several areas or divisions of the irrigated district.

Distribution features are the canals and laterals which deliver water within a specified area or division or an irrigated district. A distribution system may obtain its water canalside from a supply canal, or it may obtain the water from a group of wells or in some instances directly from the river by pumping or diversion. The exact point where the carriage system stops and the distribution system begins varies from project to project, owing to local physical conditions, terms of repayment contracts, and other factors.

Layout of the Distribution Systems

In order that the photo interpreter may be able to correlate and interpret irrigation distributaries more effectively, it is particularly necessary to understand the general plan of a distribution system.

The main carriage canals subdivide through turnouts into (1) laterals, (2) sublaterals, and (3) head-ditches, from which water is finally directed through (4) field ditches over the ground to be irrigated. (See Photo 2).

Most canals and ditches are excavated from the surface of the countryside through which they run, except where it is necessary to use earth-fill for banking where one side of the canal overlooks a depression. In this case, earth and gravel have been tamped in, then coated with clay and silt to prevent seepage. Modern canals are often concrete-lined. This pays dividends in water saved from seepage and in lower maintenance costs.

Photo 2. Aerial view of distribution features. This shows principal distribution features of Greenfields Irrigation District. (A) Greenfields Main Canal (B) Lateral (C) Sub-lateral (D) Head Ditch (E) Border Ditch, and (F) Field Ditches. Scale 1:20,000. (USDA, 1951, Photo ZS-10H-6).

All irrigation ditches ranging from main canals to sublaterals have flat bottoms with sides formed at an angle of approximately 60 degrees from the horizontal. Depth and width depend on the volume of water required. Because movement of water is actuated by gravity, the lateral gradient is a vital factor in delivering water with a maximum head, with as much velocity as is practicable, and with the precaution of preventing erosion from excessive speeds and overflows. Gradients range from 0.8 feet of fall per 1000 feet of ground distance, to 5.0 feet of fall per 1000 feet, depending on soil conditions and circuity of the ditch. On curves where the soil is fine or where speeds of water are great enough to induce erosion, riprapping is generally done. Major canals are generally silted or blanketed to prevent excessive seepage, especially where excavated materials are gravelly and readily absorb water.

In order to facilitate movement of water over places where change of level in ditches is necessary within a short distance, concrete drops with trapezoidal stilling basins are constructed. The drop expedites the change of water level and the stilling basin quiets the agitated waters before they can damage canal embankments with eddy currents and excessive speeds. Where changes of five feet or more in water level are required, there may be a series of drops at regular intervals over a distance of several yards. However, if there is a considerable change in water level within a relatively short distance so that the rate of fall is great and of considerable volume, chutes may be required. The size of the chute is necessarily smaller than that of the canal, inasmuch as increased gradient moves water more rapidly, hence requiring smaller carrying capacity. Like drops, chutes have stilling basins to quiet disturbed waters. Both the chutes and stilling basins are generally constructed of concrete.

From canals, laterals, and sublaterals, water is diverted by means of turnouts which permit the passage of water by gravity flow into smaller distributary structures. Turnouts generally consist of a wheel-and-shaft valve mechanism and a division box for controlling the flow of water. Water is impounded within the division box by means of cipoletti checkwiers, the center section of which may be covered by boards to prevent the flow of water. To one side of the trapozoidal outlet in the center of the weir is a metering guage graduated in tenths of feet. When a flow of water is desired over the weir outlet, the center board may be raised to permit the controlled flow of water.

Head ditches lead from sublaterals and conduct water to division boxes or directly to border ditches. Head ditches may service two or three farms. Border ditches originate generally at head ditches or division boxes, follow the higher edge of one or more fields, and subdivide into field ditches. Ditch riders control the flow of water onto each farm, whether ir originates at laterals or head ditches;

farmers are in control of water once it is turned onto their respective farms.

Farmers control water in border ditches by means of portable canvas dams or by temporary earthen dams. Being the smallest major distributary, border ditches are generally about one foot deep and two feet wide. The use of border ditches is particularly effective where fields have been leveled so that the slope of the field is consistent and regular. Border ditches and head ditches are generally banked high enough so that the water in them can flow above the general level of the land, thus developing a small amount of head.

Where turnouts are in use, or where it is expeditious to do so, various types of dams may be used either in conjunction with metering weirs and turnouts, or merely to stop further flow of water. There are two principal types of such dams. In the main canals, radial dams work efficiently and quickly. However, by far the greatest number of dams are those constructed of board stoppers which may be removed one at a time and which are more economical than radial dams. They are also easy to manipulate in conjunction with smaller diversion structures.

Drainage Ditches

Because of the generally saturated condition of the soil in several parts of the District, it has been necessary to construct drainage ditches to remove surplus waters. These ditches are triangular in shape as contrasted with the trapezoidal shape of major distributaries. They are about ten feet wide and have been excavated to a depth of approximately eight feet. Their location is below and generally parallel to major canals and laterals and in depressions from which there are no natural outlets.

Non-Irrigation Structures

There are a number of structures which are not directly concerned with the distribution of water, but are associated with an irrigation system. Most important are bridges for highways crossing canals and laterals having greater than 50-second-feet capacity. Distributaries having capacities of less than 50 second-feet are generally extended under highways, commonly without change in their water level, in corrugated metal pipe culverts. These pipes vary in length but have a minimum diameter of 20 inches to reduce possibilities of weed clogging. Where drainage ditches intersect minor distributaries, water is passed through cross-drainage culverts across drainage ditches. Likewise, where drainage ditches with minor flows of water are forced to traverse major water distributaries, subsurface culverts meet the need.

Materials which may be ordinarily piled beside excavations are commonly graded so as to form a roadway parallel to the waterways. This artificial bank stands 5 to 6 feet above the general level of the land. The roadway on top of the bank is used by ditch riders to attend their work of supervising and operating water distribution facilities during the dry season.

Conclusions

Responsibility for the design and construction of structures essential to the storage, diversion, conveyance, delivery, and distribution of water to irrigators rests with the engineer. It is important, therefore, that such structures be built so that they may be relied on during critical periods. The failure of a storage dam, as a result of bombing operations or because of poor design, may cause the loss of large property investments and sometimes the loss of lives of many people. The destruction of a diversion dam or the breaking of a canal may cause the loss of all or part of the structure and very often the loss of valuable crops by the failure of water when it is needed.

Irrigated lands are generally situated great distances from the source of water supply. Water obtained from natural streams and from surface reservoirs, as a rule, must be conveyed farther than water obtained from underground reservoirs. Carriage canals may vary from a few miles to 100 or more miles in length.

It is necessary, therefore, that a key for the photo identification of irrigation structures belonging to a gravity-flow irrigation system consist of three parts: (1) a key for the identification of storage facilities; (2) a key for the identification of carriage system structures; and (3) a key for the identification of distribution features.

Aerial Photo Identification of Structures
Associated with the Greenfields Irrigation District:
Storage Facilities

The Gibson Dam

The Gibson Dam is located on the North Fork of the Sun River approximately 37 miles west of Fairfield, Montana, headquarters of the Greenfields Irrigation District. The surface of the limestone bedrock on which the dam has been built is very seamy with pronounced stratification. The structure is a concrete arch 195.5 feet high with a crest length of 960 feet, a crest width of 15 feet, and a base width of 87 feet. (See Photos 3-A and 3-B). It has a hydraulic height of 174 feet. Total volume of material in the dam is 161,696 cubic yards.

A glory hole spillway is located at the north end of the dam. (See Photos 3-A and 3-B). It has a capacity of 50,000 cubic feet per second when the water surface is at elevation 4,729 feet. The glory hole, shaft, and 29.5-foot diameter tunnel are controlled by six 34 x 12-foot radial gates at crest elevation 4,712 feet above mean sea level.

Outlet structures for the dam are two 72-inch diameter conduits through the base of the dam, each with a 60-inch emergency slide gate and a 60-inch needle valve on the downstream end. (See Photo 4). The maximum capacity of the outlets is 2000 cubic feet per second.

Photos 3-A and 3-B. Stereogram of Gibson Dam on North Fork of Sun River about 37 miles west of Fairfield, Montana. (A) Gibson Dam (B) Glory hole spillway (C) Outlet Structures. Scale: 1:20,000. (USDA, 1939, Photos CO-41-74; CO-41-75).

Photo 4. Front view of Gibson Dam. Note outlet structures at base of the dam.

Gibson Reservoir

Waters stored by the Gibson Dam occupy a depression known as Gibson Reservoir with an active irrigation storage capacity of 105,000 acre-feet, covering an area of 1,360 acres. It extends upstream for a distance of seven miles, and is approximately one mile wide. Construction by the Utah Construction Company was completed according to contract specifications in July, 1929, and storage of water begun immediately. In 1930, effective use of the waters of Gibson Reservoir was being made.

Photo 5. Aerial photo of Gibson Reservoir. Waters are impounded by Gibson Dam for a distance of 7 miles upstream. Scale 1:20,000 (USDA, 1939, Photo CO-41-76)

Photos 6-A and 6-B. Stereopair of view from north shore of Reservoir looking east toward glory hole spillway and crest of Gibson Dam.

Photo 7. View from north shore of Gibson Reservoir, looking south.

Aerial Photo Identification of Structures
Associated with the Greenfields Irrigation District
<u>Carriage System</u>

Diversion Dam

Diversion Dam was completed in 1909 as the first structure for the diversion of Sun River waters. Prior to the construction of Gibson Dam, Diversion Dam furnished the only facility for claiming waters of Sun River for purposes of irrigation. Gibson Dam has replaced its function as a regulator, insuring adequate water supply at all times. Now Diversion Dam is a secondary structure in the storage system, although it still retains its function of diverting waters from Sun River.

Diversion Dam is located downstream 3 miles from Gibson Dam. It is a concrete arch-gravity structure. (See Photos 8-A and 8-B). It has a structural height of 131 feet; crest length of 243 feet; crest width of 7.5 feet; and a base width of 40 feet. The outlet is 11 feet in diameter and has a maximum capacity of 1400 cubic feet per second at a surface elevation of 4,471.1 feet above sea level.

Water is diverted directly at Diversion Dam into Willow Creek Feeder Canal to Willow Creek Reservoir; thence to Fort Shaw Irrigation District. Water is also diverted at the same point to the Pishkun Supply Canal and Pishkun Reservoir; thence to Greenfields Irrigation District.

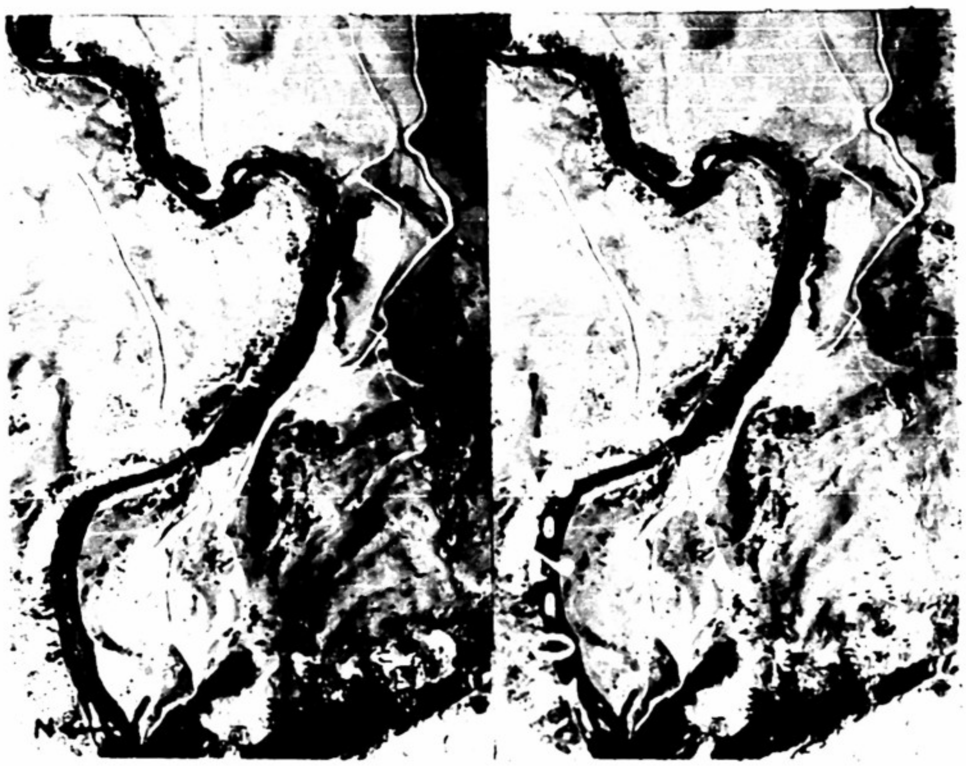
Photos 8-A and 8-B. Stereogram of Diversion Dam. (A) Dam (B) Water is carried in underground conduit from Diversion Dam (C) Siphon carrying water to start of Pishkun Supply Canal. Scale 1:20,000. (USDA, 1939, Photos CO-41-65; CO-41-66)

Photo 9. Diversion Dam. Water is diverted from Sun River at this dam into the North Side Canal System, supplying irrigation water for the Greenfields Irrigation District. Outlet is to the left.

Siphon of Pishkun Supply Canal

Water taken from Diversion Dam flows through a 650-foot tunnel through the canyon wall on the south side of Sun River; thence through a conduit 870 feet in length. At the end of the conduit, the water is taken northward beneath the Sun River through a siphon, 700 feet in length, to the start of the Pishkun Supply Canal. (See Photos 11-A and 11-B).

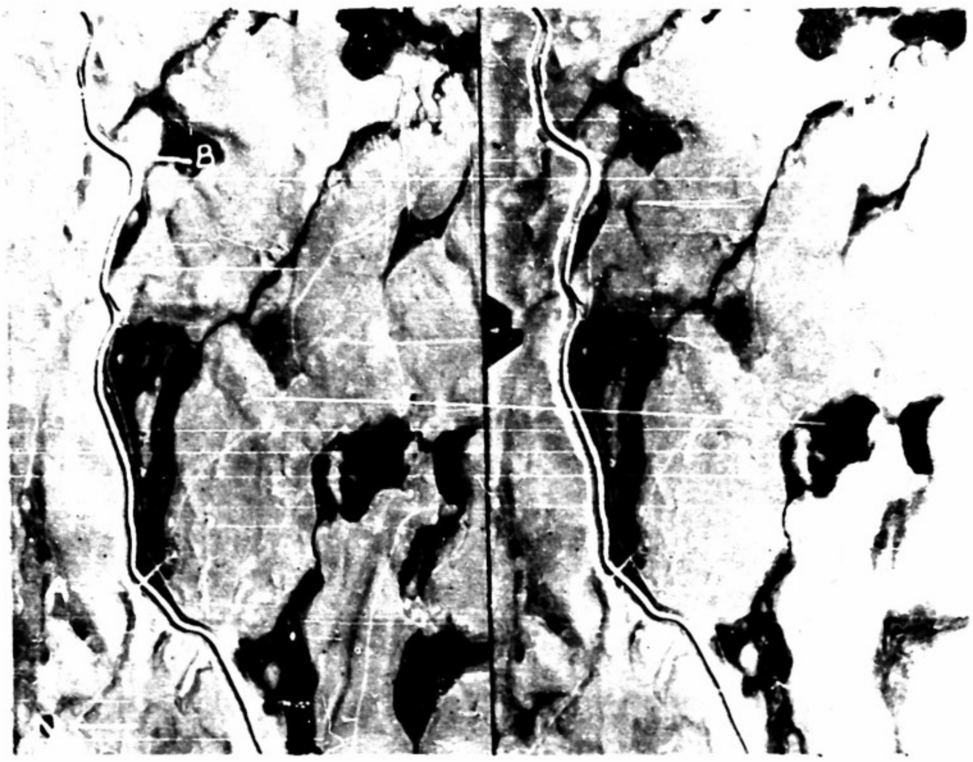
Photo 10. Siphon through which water is carried from south side of Sun River to north. Note that the location of the siphon on the far slope is indicated by the broken surface where the trench containing the siphon has been filled. The embankment at the far end of the siphon marks the start of the Pishkun Supply Canal. Road which crosses river on bridge continues along base of south bank of Pishkun Supply Canal to Pishkun Reservoir.



Photos 11-A and 11-B. Stereogram of the siphon through which water flows northward beneath the Sun River to the Pishkun Supply Canal. (A) Siphon (B) the beginning of the Pishkun Supply Canal and (C) roadway constructed at the base of the south bank of the canal. Scale 1:20,000. (USDA, 1951, Photos ZS-5H-148; ZS-5H-149).

Pishkun Supply Canal

The Pishkun Supply Canal is built through the rough foothill country eastward from the eastern front of the Lewis Range, between the Diversion Dam and the Pishkun Reservoir, a distance of 12 miles. The surface materials of rock and coarse gravel cause excessive seepage of water and have been the source of much trouble. The canal has a capacity of 1200 cubic feet per second.



Photos 12-A and 12-B. Stereogram of Pishkun Supply Canal between Diversion Dam and Pishkun Reservoir. On stereogram note (A) bridge over canal and (B) blanketing of canal on outside of bend to prevent erosion and seepage. Scale 1:20,000. (USDA, 1951, ZS-5H-5, ZS-5H-4)

Photos 13-A and 13-B. Stereopair of Pishkun Supply Canal looking westward toward Lewis Range from eastern terminus of Canal. Note embankment on south side of canal.

Pishkun Reservoir

The Pishkun Reservoir occupies a basin which is enclosed by an inner moraine of the former Sun River Glacier. (See Photo 14). The reservoir site embraces a series of connected lake beds almost on the divide between the Sun and Teton River drainage systems, approximately 14 miles east of Diversion Dam.

Pishkun Reservoir has an active storage capacity of 32,050 acre-feet. It is formed by a series of eight earth-fill dikes, with a crest width of 20 feet, an average maximum height of 23.5 feet, and an overall length of 9,050 feet. (See Photos 15 and 16-A & B). The outlet is a 12-foot diameter concrete conduit with a maximum capacity of 1600 cubic feet per second.

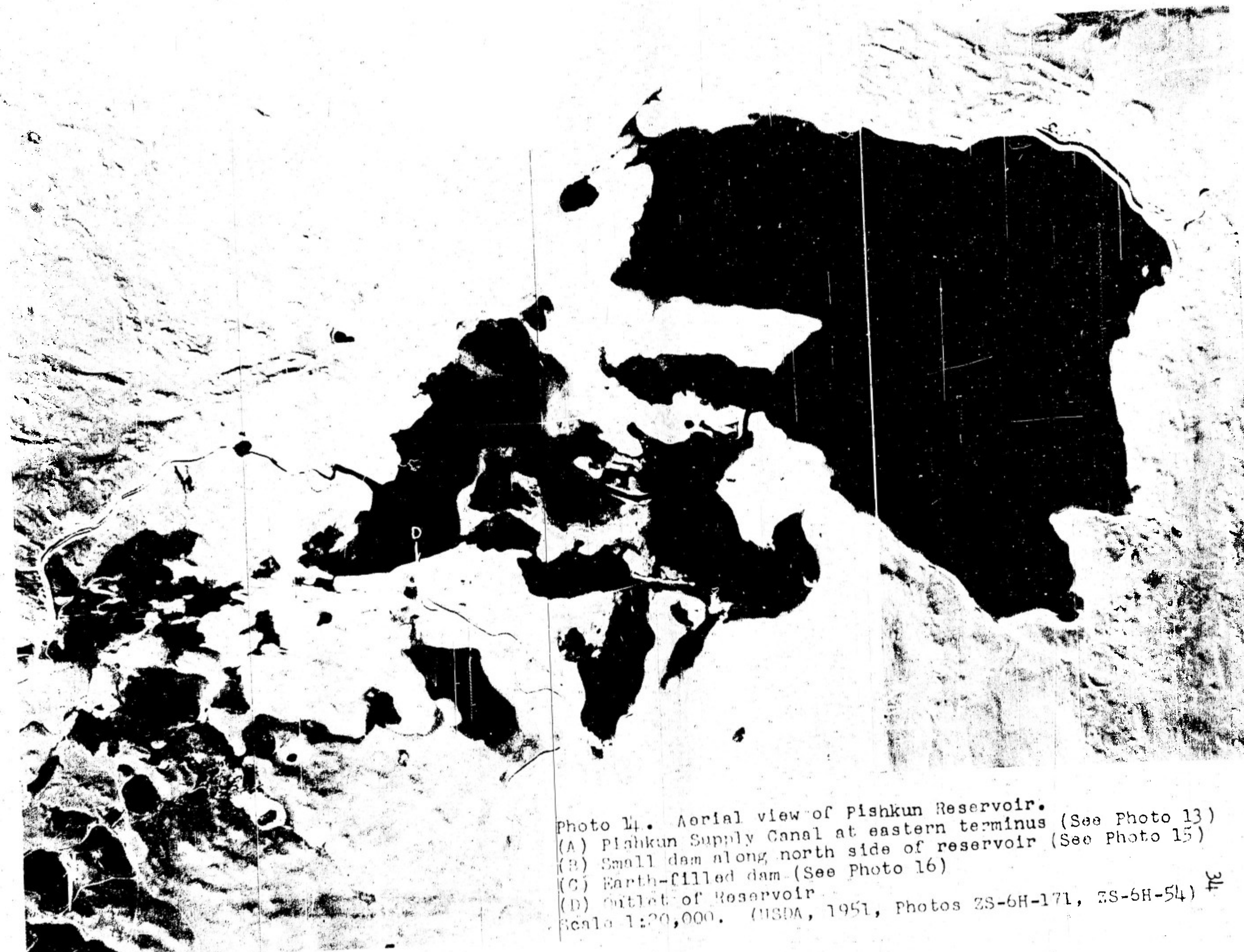


Photo 14. Aerial view of Pishkun Reservoir.
(A) Pishkun Supply Canal at eastern terminus (See Photo 13)
(B) Small dam along north side of reservoir (See Photo 15)
(C) Earth-filled dam (See Photo 16)
(D) Outlet of Reservoir
Scale 1:20,000. (USDA, 1951, Photos ZS-6H-171, ZS-6H-54)

Photo 15. Small dam along north side of reservoir. (See Photo 14)

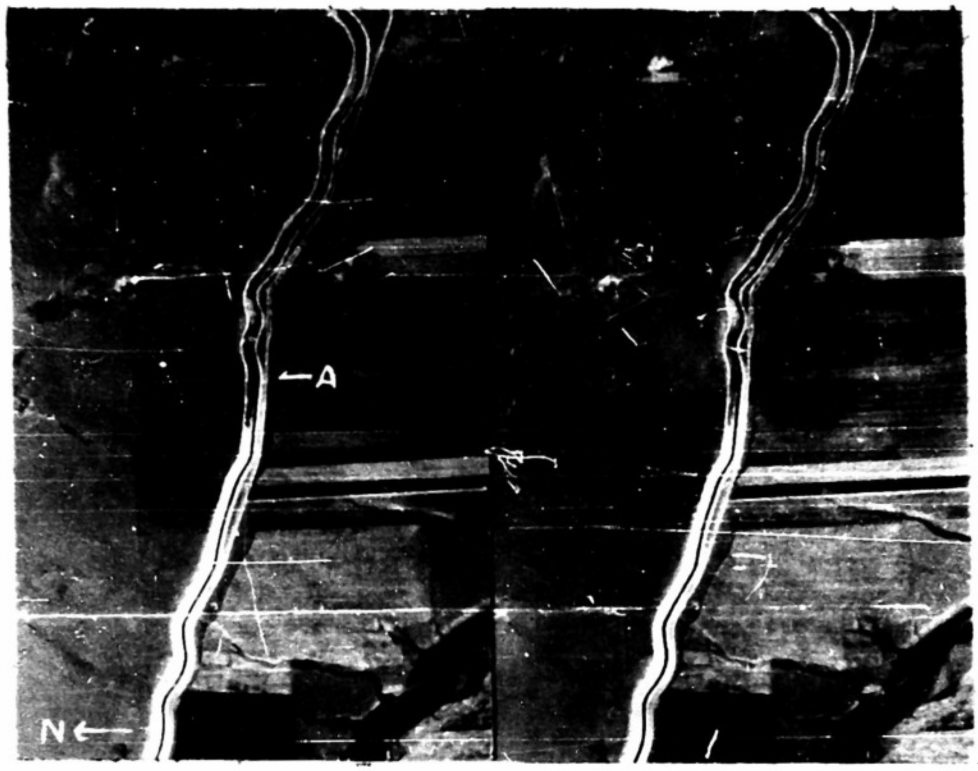
Photos 16-A and 16-B. Stereopair of earth-filled dam at the northeastern end of Pishkun Reservoir. Note road on top of dam. Picture taken looking southeastward from northwest end of dam. (See Photo 14)

Sun River Slope Canal

From Pishkun Reservoir the irrigation waters flow southeastward for 25.9 miles through the Sun River Slope Canal to the head of Big Coulee into which some water is released. Beyond Big Coulee the carriage system is known as the Spring Valley Canal, which extends eastward 14.2 miles to Fairfield.

The maintenance of the Sun River Slope Canal has been complicated by the rolling character of the area. It has been necessary to cement the sides and bottom of the canal for the first ten miles southeast of Pishkun Reservoir.

The Sun River Slope Canal has a capacity in excess of 1200 cubic feet per second. The first major turnout into a lateral is eight miles southeast of the Pishkun Reservoir.



Photos 17-A and 17-B. Stereogram of Sun River Slope Canal. Material excavated from the canal appears as a wide, light-colored ribbon along the bank of the canal. Northern bank is light in tone due to the lack of vegetation. Base width of canal is about 60 feet, water depth about 7½ feet. Road width about 20 feet. Side slopes of canal: 2 to 1. (A) Point at which Photo 18 was taken. Scale 1:20,000 (USDA, 1951, Photo ZS-8H-25-26)

Photos 18-A and 18-B. Stereopair of Sun River Slope Canal looking eastward from point indicated on stereogram above.

Aerial Photo Identification of Structures

Associated with the Greenfields Irrigation District:

Distribution Features

General Characteristics of Distribution Features Greenfields Irrigation District

The distribution features of a gravity-flow irrigation system generally consist of a main canal with its laterals, sublaterals, and head ditches. From the head ditches water is directed through border ditches from which it is spread over the ground by means of field ditches.

In general, laterals in the Greenfields Irrigation District have been designed to serve from 3,000 to 3,500 acres. A lateral with its sublaterals has an average total length of 12 to 15 miles.

For the most part the canals and ditches of the distributary system of the Greenfields Irrigation District have been excavated from the surface of the countryside across which they traverse. Only where one side of the canal overlooks a depression has it been necessary to use earth-fill for banking. In such a case, earth and gravel have been tamped in, then coated with clay and silt to prevent seepage.

All irrigation ditches ranging from main canals to sub-laterals have flat bottoms with sides formed at an angle of approximately 60° from the horizontal. The depth and width depend upon the volume of water to be carried.

Because the movement of water is actuated by gravity, the lateral gradient is a vital factor in delivering water with a maximum head, with as much velocity as is practicable, but with the precaution of preventing erosion from excessive speeds and overflows. Gradients range from 0.8 feet of fall per 1,000 feet of distance to 5.0 feet of fall per 1,000 feet, depending upon soil conditions and on the circuity of the ditch. On curves where fine materials constitute mantle rock, and where speeds of the water are great enough to induce erosion, riprapping is commonly done.

Photo 19. General aerial view of a portion of the Greenfields Irrigation District, showing the distribution features. Scale 1:20,000. (USDA, 1951, Photo ZS-10H-6).

(A) Greenfields Main Canal
(B) Lateral
(C) Sublateral
(D) Head ditch
(E) Border ditch
(F) Field ditches
(G) Turnout
(H) Check Dam*
(I) Division Box*
(J) Drop*
(K) Chutes
(L) Stilling Basin
(M) Sluice
(N) Conduit
(O) Drainage Ditch

*These distribution features not shown on above photograph

Greenfields Main Canal

At a point near the village of Fairfield the Spring Valley Canal becomes known as the Greenfields Main Canal. (See Figure 2). This is the major distribution feature of the Greenfields Irrigation District. The Greenfields Main Canal has an initial capacity of 1,200 cubic feet per second. This diminishes until it has a terminal capacity of 10 cubic feet per second.

About 2 miles below the starting point of the Greenfields Main Canal, the Greenfields South Canal relieves the former of a capacity of 425 cubic feet per second and extends 16.7 miles into the southeastern corner of the Greenfields Bench.

The first lateral turnout of the Greenfields South Canal carries water northeastward and downstream, where eventually the surplus water is returned to the Greenfields Main Canal. The second turnout allows water to enter the Mill Coulee Canal which has a capacity of 54 cubic feet per second.

The bottom width of the Greenfiolds Main Canal is 32 feet; the sides have a 2 to 1 slope; the water averages 5 feet depth; and the canal has a total depth of 7 feet. (See Photo 0). Materials excavated from the canal have been utilized in the construction of the embankments or as backfill. The banks of the canal are 8 feet wide, 7 feet high, and have a 2 to 1 slope. A roadway has been built along the top of one bank.

Photos 20-A and 20-B. Stereogram of the Greenfields Main Canal. Note the roadway along the canal embankment. The embankment was constructed with material excavated from the canal. On the stereogram the vegetation appears as a dark margin along both sides of the road. (A) Indicates point at which Photo 21 was taken. Scale 1:20,000. (USDA, 1951, Photos ZS-10H-5, ZS-10H-6)

Photos 21-A and 21-B. Stereopair of Greenfields Main Canal, looking southwest from a bridge on Third Lane Road, at the edge of the southwest portion of Section 31, T 22N, R 2W. Road is on the right bank of the canal. (See Photo 20).

Head Ditches

Head ditches lead from sublaterals. Head ditches may serve two or three farms, where they conduct water directly to border ditches or to division boxes. (See Photo 22). Head ditches are the smallest units of the distributary system, through which the flow of water is controlled by ditch riders.

Border Ditches

Border ditches originate generally at head ditches or division boxes and follow the higher edges of one or more fields. The border ditches are generally about one foot deep and two feet wide. The use of border ditches is particularly effective where the fields have been leveled so that the slope of the field is consistent and regular. Border ditches and head ditches are generally banked high enough so that the water can flow above the general level of the land, thus permitting a small amount of head. Farmers assume control of the flow of the irrigation water after it has been diverted into the border ditches.

Field Ditches

The border ditches are subdivided into field ditches. (See Photo 23). These conduct the water directly to the crops to be irrigated.

Photo 22. A head ditch along a highway. Note the turnoff into the border ditch. For aerial view of above ditch see (D) on Photo 19.

Photo 23. Field ditches leading from a border ditch. Hay has been cut and the field is being used as a pasture for dairy cows. These ditches appear on aerial photographs as roughly parallel features extending northeastward from the border ditch toward the drainage ditch. For aerial view of above field ditch see (F) on Photo 19.

Turnouts

From the main canal, laterals, sublaterals, and smaller ditches, the water is diverted by means of turnouts. These permit the passage of water by gravity flow into successively smaller distributary units. Turnouts generally consist of a wheel-and-shaft valve mechanism for permitting a flow of water as desired.

Check Dams

Where turnouts are in use, or where it is expeditious to do so, various types of dams may be used. In the main canals the radial dams work efficiently and quickly. However, by far the greatest number of dams consist of board stoppers which may be removed one at a time and which are more economical to construct than radial dams. They are also easier to manipulate in conjunction with smaller diversion structures.

Photo 24. A turnout from the Greenfields Main Canal. Note the check dam in the center which can be constructed with board stoppers. The turnout to the lateral is on the left.

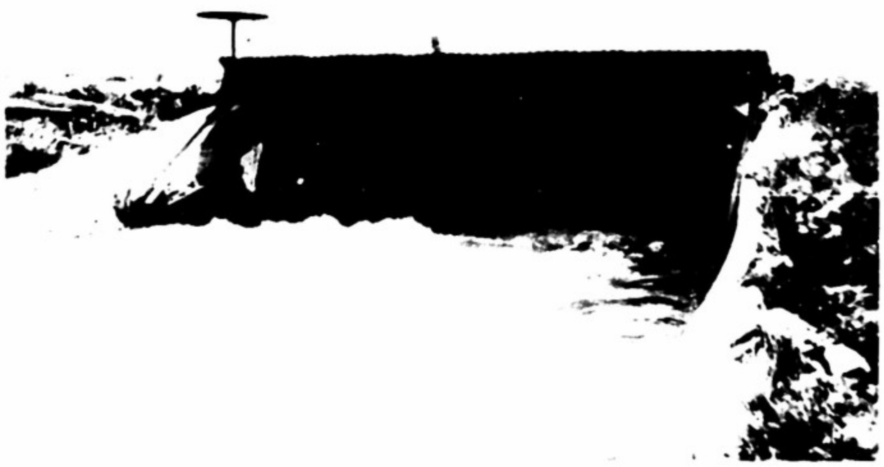


Photo 25. A radial check dam in the Greenfields Main Canal. These dams work efficiently and quickly, but most dams consist of board stoppers which may be removed one at a time and which are more economical to construct than radial dams.

Special Structures

Water flows from head ditches into cement division boxes from which it is then turned out into border ditches. The water is contained within the division box by means of a cipoletti checkweir, the center section of which may be covered by boards to prevent the flow of water.

On one side of the trapezoidal outlet in the center of the weir is a metering gauge which is graduated in tenths of feet. When a flow of water is desired over the weir outlet, the center board may be raised to permit the controlled flow of water.

Photo 26. Ground appearance of a turnout from a head ditch northward into a border ditch. Note the wheel-and-shaft mechanism for controlling the flow of water. The water flows from the turnout into a division box, where the water is impounded by means of a checkweir. Note the trapezoidal shape of the checkweir. The center section of the weir may be covered by boards to prevent the flow of water northward and to direct it east or west as desired. For aerial view of above feature see (G) on Photo 19.

Photo 27. A closeup of a cipoletti checkweir. Note the metering gauge on the right side of the outlet in the center of the weir. Not possible to detect on aerial photographs.

Miscellaneous Features

In order to expedite the movement of water where a change of level in ditches is necessary within a short distance, concrete drops with trapezoidal stilling basins are often constructed. The drop accomplishes the change in water level and the stilling basin quiets the agitated water before it damages the canal embankments with eddies and excessive speeds.

Where changes in water level of five feet or more are required, there may be a series of drops at regular intervals within a distance of several yards. However, if there is a considerable change in water level within a relatively short distance, so that the rate of fall is great and of considerable volume, concrete chutes may be required. The width of the chute is necessarily smaller than that of the canal since the increased gradient moves the water more quickly. Like drops, chutes have stilling basins to quiet the disturbed water.

Often sluices and conduits are necessary to carry laterals, sublaterals, and head ditches across roads or over drainage ditches. These may be constructed of wood or galvanized iron.

Photo 28. A single drop. These are located where there is a change of level of less than 5 feet. On aerial photos a drop appears only as a dark indistinct feature in the canal. Often drops are located where a change in level is associated with a change in direction. The stilling basin below the drop appears on aerial photos as a widening in the canal.

Photo 29. A series of drops. Note the stilling basins at the base of each drop.

Photos 30-A and 30-B. Stereogram of a chute. Constriction in width of canal is apparent. Abrupt change in direction of flow at upper end of chute is characteristic. The check at upper end of chute is scarcely discernible. (A) Funnel-shaped upper end of chute indicates direction of flow. (B) Stilling basin at lower end of chute is identified by agitated water which appears foamy white on the lower side of check. (C) Gradual curve of the canal leaving stilling basin indicates the lower end of chute. Scale 1:20,000. (USDA, 1951, Photo ZS-10H-5, ZS-10H-6).

Photos 31-A and 31-B. Stereopair of chute indicated in Photo 30, page 52, looking down slope of chute. Observe inclined concrete sides and in the right foreground may be seen a portion of the wider, funnel-shaped upper end of chute. Check and stilling basin may be observed at foot of chute, where Greenfields Main Canal turns toward east-northeast. A main lateral turns toward the west and carries water beneath the road. Also shown as (K) and (I) on Photo 19.

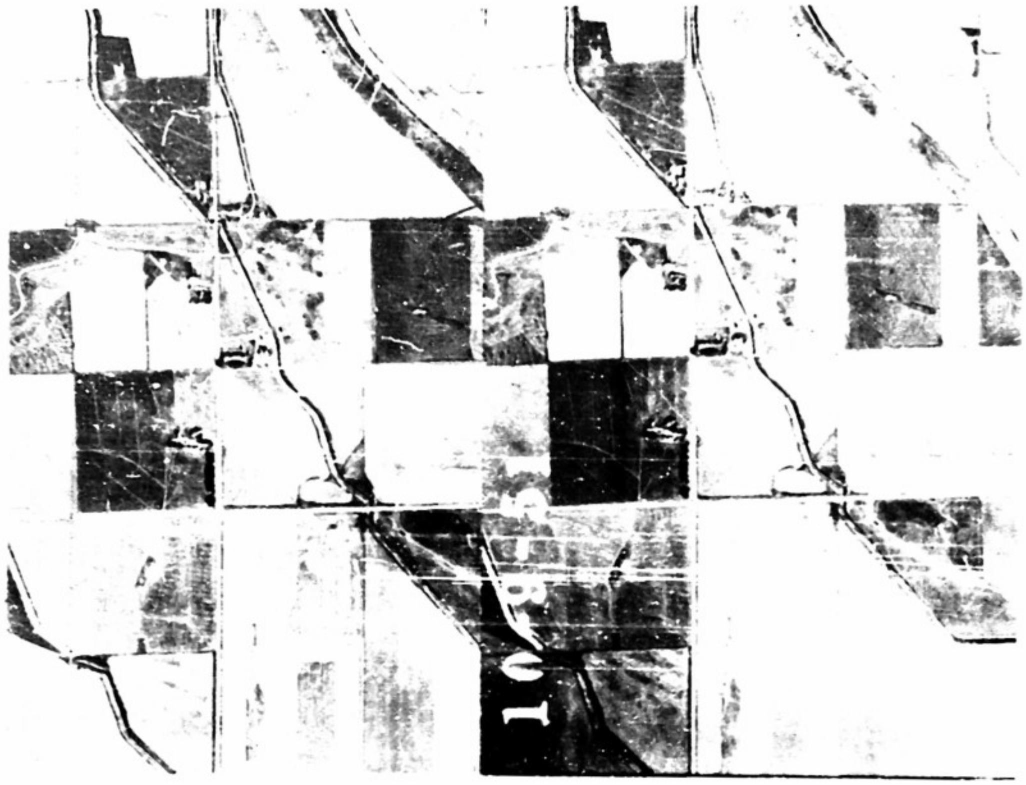
Photos 32-A and 32-B. Stereopair of a wooden sluice; looking east-northeasterly along the drainage ditch. The sluice carries a head ditch over the drainage ditch. For aerial view of above feature see (M) on Photo 19.

Photos 33-A and 33-B. Stereopair of a large galvanized conduit, which carries water in a sublateral across a drainage ditch. For aerial view of above feature see (N) on Photo 19.

Drainage Ditches

Because of the generally saturated condition of the soil in several parts of the Greenfields Irrigation District, it has been necessary to construct drainage ditches to remove the surplus water that has accumulated as a result of irrigation and seepage losses. These ditches are commonly triangular in shape as contrasted with the trapezoidal shape of major distributaries. They are about ten feet wide and have been excavated to a depth of about eight feet. Their location is below and generally parallel to major canals and laterals or in depressions from which there are no natural outlets. There is no unit of the Greenfields Irrigation District which is entirely free from drainage problems, but the problem is more acute where surface configuration and impervious soils result in a high water table.

In some cases, water from drainage ditches on the upper benches flows into sublaterals at lower levels if adequate quantities of usable water have been collected. Otherwise, drainage ditches empty into wasteways.



Photos 34-A and 34-B. Stereogram of drainage ditch. Its tone is much darker than a canal, due to its greater depth. Drains are constructed on straight lines wherever practical. Scale 1:20,000. (USDA, 1951, Photos ZS-10H-5, ZS-10H-6).

Photos 35-A and 35-B. Stereopair of drainage ditch, looking southwesterly along the ditch from a road. Note that there is no road along either embankment of the drainage ditch. Also note the vegetation in the stagnant water. For aerial view of above feature see (O) in Photo 19.